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OPTICAL MASS MEMORY ADVANCED TECHNOLOGY DEMONSTRATION

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1.0 INTRODUCTION

This document is the Final Technical Report (CDRL A002) for contract number F30602-93-C-0194, entitled "Optical Mass Memory Advanced Technology Demonstration (OMM ATD)". The OMM ATD effort was a six month effort, which ran from 6 August 1993 through 6 February 1994. Synectics Corporation was the prime contractor, with Martin Marietta Government Communications Systems serving as a subcontractor on the effort.

New optical memory concepts such as Optical Random Access Memories, Optical Cache Memories, and Optical Associative Memories are rapidly reaching maturity. When fielded in the next few years, these systems will provide a significant benefit in relieving the I/O bandwidth bottlenecks currently experienced by supercomputer systems when accessing very large databases. In the near future, computer designers will have memory and interconnect devices with capacities in the Terabytes, throughput rates of Gigabits per second, and access times in the microseconds. The purpose of this effort was to define and demonstrate a hardware and software testbed for demonstrating and evaluating these data storage technologies for use in an operational environment.

For purposes of the initial demonstration, this effort focused on a comparison and evaluation of three types of optical mass storage:

- √ The Air Force Strategic/Tactical Optical Disk System (S/TODS)
- √ Commercial CD-ROM
- √ State of the art 5 1/4" magneto-optical (MO) rewritable disk

Under this task, one of the optical mass memory systems evaluated was the Air Force Strategic/Tactical Optical Disk System (S/TODS). The S/TODS represents a new generation of rewritable optical disk systems designed to be capable of satisfying the basic goals of high-performance access to large on-line databases in a rugged environment.

2.0 SCOPE

This final technical report serves four purposes. First, it documents the purpose of the OMM ATD effort, and identifies, in detail, each of the technical tasks to have been performed. Second, it reviews the results which were obtained during the performance of each of the technical tasks. Third, lessons learned, and recommendations for further work, are identified and discussed. Finally, Appendix A and Appendix B serve as user's manuals for the software applications which were developed during the performance of the OMM ATD effort.

3.0 REVIEW OF TASKS

The OMM ATD effort consisted of four technical tasks:

√ Identify and assemble a suite of hardware capable of demonstrating and evaluating three representative optical mass storage technologies:

- COTS CD-ROM
- COTS 5 1/4" Rewritable Magneto-Optical (MO) Disk
- Air Force Strategic/Tactical Optical Disk System (S/TODS)

√ Identify and assemble a suite of software and data capable of demonstrating and evaluating three parameters of optical mass storage technologies:

- Data Capacity
- Data Transfer Rate
- Data Access Time

√ Interface the S/TODS to a Sun workstation, to allow the use of the S/TODS as a standard Unix file system device

Each of these tasks is outlined in more detail in the sections below.

3.1 IDENTIFY AND ASSEMBLE HARDWARE SUITE

The intent of this task was to identify and assemble a number of hardware components, which could form the basis for a comprehensive testbed for the evaluation of optical mass memory technologies. In order to achieve this goal, the hardware suite had to achieve a number of goals:

√ The workstation at the heart of the testbed had to be representative of workstations that would likely be utilized in real-world environments. The overall purpose of the OMM ATD effort was to provide a means of evaluating and demonstrating the performance of optical mass memory technologies, and determining their applicability to the real-world applications being used by operational customers.

√ Common / open physical interfaces were to be utilized wherever possible. In order to maintain relevance to the "real world", the devices utilized in the OMM ATD would ideally interface to the workstation using standard interfaces, such as SCSI.

√ The environment had to be expandable, in order to ensure that a wide range of technologies could be evaluated. In order to assure such expandability, a mix of commercial and emerging technologies were to be evaluated under the initial environment.

The hardware suite which was assembled for this effort is documented in Section 4.1 of this document.

3.2 IDENTIFY AND ASSEMBLE SOFTWARE / DATA SUITE

The intent of this task was to identify and assemble a suite of software and data which could be used to evaluate three key performance parameters for any mass memory technology:

- √ **Data Capacity** - Refers to the total "volume" of data that a given device is capable of storing at any given time. Generally defined in terms of megabytes, gigabytes, and terabytes. Mass memory systems, almost by definition, have the data capacity to store a minimum of several hundred megabytes of data.

- √ **Data Access Time** - Refers to the amount of time required to locate a given byte of data on the storage media, and position the retrieval device in such a way that the desired data can be read from the media. In any storage device, there will be some delay, or latency, between the time when a given byte of data is requested, and the time that it is actually available for retrieval. Several factors can contribute to this latency. For example, in a disk-based storage system, some amount of time is required for the disk platter to rotate to the point that the data to be retrieved is under the read head. Additional time is required to translate the read head along the radius of the disk to locate the head over the appropriate "track" of data. The total time required to place the device in a state which will allow the data to actually be read is the data access time.

- √ **Data Transfer Rate** - Refers to the speed with which data can be moved from the storage media to the host workstation, once the data have been located on the storage media. Data transfer rate excludes the data access time, and includes only the amount of time required to move the located data off the media and across the interface to the host system. A number of factors can contribute to data transfer rate, including the performance of the read head, and the operating speed of the data interface and bus.

A number of factors where taken into account in assembling the software and data suite for this effort. First, the assembled software and data had to be representative of the types of applications and data that would be used by operational users. In the intel community this frequently means database retrieval and display applications utilizing a collection of digital maps, digital imagery, and textual reports.

Second, the assembled software and data had to have the ability to perform a collection of random and sequential I/O. Both data access time and data transfer rate performance can be drastically affected by differences between random and sequential input. For example, a device which has very high data transfer performance when reading bytes which are contiguously located on a disk platter may have very poor performance when data must be read from a number of random locations on the platter.

Third, the assembled software and data had to allow for the retrieval of very large data files. Due to a number of factors, including data access time, caching, and interface characteristics; storage devices often perform better when reading very large files.

Finally, it was considered important to provide both qualitative and quantitative measures of performance for all of the devices evaluated under this effort. A typical user of a storage system may have very little grasp of, or interest in, the performance difference between a device capable of transferring 150 KB/sec and a device capable of transferring 4 MB/sec. The typical

user is much more interested in seeing a realistic example of the difference in the response time of his/her typical application when working with the storage system being evaluated. Therefore, an effort was made to select applications and data which would be capable of performing a quantitative measure of data access time and data transfer rate, and would also display the retrieved data visually.

3.3 S/TODS - SUN INTEGRATION

The intent of this task was to allow the Air Force Strategic/Tactical Optical Disk System to function as a standard Unix disk storage device on a Sun workstation. The S/TODS is a high performance, ruggedized, optical disk system capable of storing 6 GB of data per side of a 14 inch rewritable optical disk platter. The current S/TODS contains a single-sided drive, requiring that the optical platter must be physically removed from the drive and turned over in order to access the storage capacity of the other side of the disk. A jukebox configuration, capable of automatically flipping the optical platters, is currently under development.

The S/TODS has the following characteristics:

Interface:	Differential SCSI-II
Mounting:	19" Rack
Size:	4.8 cu. ft
Weight:	165 lbs
Power:	120 VAC, 400 Hz, 20 A, single phase
Data Transfer (Burst):	40 Mb/s
Data Transfer (Cont.):	0 to 25 Mb/s

Initial development and testing of the S/TODS was performed using the drive as a "raw" storage device. Diagnostic data was sequentially fed to the S/TODS and recorded on the optical media. Tests were then made to ensure that the data had been properly recorded and retrieved. These tests demonstrated that the S/TODS was, in fact, capable of performing in accordance with its design goal's when used in a raw device mode.

However, in order to be used in a typical workstation environment, the S/TODS must have a "file system" capability. A file system organizes the data on the physical platters into a structure which allows data to be stored and retrieved on a random access basis. In raw mode data are recorded, contiguously, from a set starting point to a set ending point on the disk platter. Raw storage provides little flexibility in storing and retrieving multiple files, or storing and retrieving data in any but a sequential process.

A major goal of the OMM ATD effort was to integrate the S/TODS with an off-the-shelf Sun workstation, allowing the workstation to access the S/TODS as a standard disk drive device containing a Unix file system. By performing this integration, the S/TODS can be used as a rugged storage system in a mobile workstation environment, to support typical user applications such as mission planning, threat analysis, image processing, briefing preparation, etc.

Our initial analysis determined that two approaches could be used to interface the S/TODS to the Sun workstation. The first approach was to build a "block device driver" for the Sun workstation. Under this approach, a piece of software would be developed that would allow the SunOS 4.1.3 operating system to translate data into an S/TODS compatible format, and would allow the Sun operating system to issue the appropriate commands to the S/TODS to allow the data to be stored and retrieved.

The second approach was to equip the S/TODS with a programmable SCSI-II interface, which would allow the S/TODS to "speak the same language" as the Sun workstation. Under this approach all translation would be handled by the S/TODS, allowing the Sun workstation to view the system as if it were any off-the-shelf Sun compatible disk drive.

3.4 DEMONSTRATION

The intent of this task was to provide a demonstration of the assembled software and data, and to utilize the assembled software and data to analyze the performance of the S/TODS, the COTS CD-ROM, and the COTS magneto-optical disk drive. This analysis would allow us to judge the relative performance of the three devices, and to evaluate the success of the S/TODS integration task.

4.0 RESULTS

The tasks described above were carried out between August 1993 and February 1994. The following sections document the results of each task. Section 5 documents lessons which were learned during the performance of this effort, and makes specific recommendations for additional R & D based on the results documented here.

4.1 IDENTIFY AND ASSEMBLE HARDWARE SUITE

Three optical storage devices were selected for inclusion and evaluation under the OMM ATD effort:

- √ COTS CD-ROM
- √ COTS Magneto-optical (MO) disk
- √ Air Force Strategic/Tactical Optical Disk System (S/TODS)

The first two, CD-ROM and MO disk, were selected due to the fact that they represent the current state-of-the-art in off-the-shelf optical storage. The DoD is currently engaged in a trend toward maximum utilization of COTS hardware and software. However, off-the-shelf components may not always be suitable for all purposes. For this reason, it is necessary to provide a capability for evaluating these components to determine their suitability for any given purpose.

The S/TODS was selected for inclusion in this environment due to the fact that it represents an advancement in the current state-of-the-art in off-the-shelf optical storage technology which has been enhanced for military use. The S/TODS was included as a means of evaluating its enhanced performance, and the degree to which its enhanced technology fulfills functional requirements which can not be met by off-the-shelf components.

4.1.1 COTS CD-ROM

A COTS CD-ROM drive was obtained, on loan, for this effort. CD-ROM drives are currently classified by their speed. A "Single-Speed" CD-ROM is capable of transferring up to 150 KB/sec of data. A "Double-Speed" CD-ROM drive can transfer twice that volume of data, or approximately 300 KB/sec. Predictably, triple-speed and quad-speed drives transfer 450 KB/sec and 600 KB/sec respectively. Currently, double-speed drives are most common, with triple-speed drives having been on the market for only a short time, and quad-speed drives having just been introduced. Under the OMM ATD effort, a double-speed drive was utilized, due to the fact that it is the most standard and most common.

CD-ROMs are capable of storing up to approximately 600 MB of data on a single 5 1/4" polycarbonate plastic disk with a metallic substrate. Because the CD-ROM is read-only, no new data may be added to a given dataset. Files are written on the CD-ROM in any of a number of standardized formats. Two of the most common are referred to as "High Sierra File System", or

HSFS, and ISO-9660. All data obtained and used under this effort conformed to the High Sierra standard, as it is the best supported CD-ROM format under the SunOS operating system. A number of attempts were made to utilize data stored in an ISO-9660 format, with mixed results. The majority of the ISO-9660 disks which we attempted to mount on the Sun, under SunOS 4.1.x, were unreadable. Theorizing that a more recent release of the operating system may support the ISO format we attempted the same operations on another Sun workstation running under the Solaris 2.3 operating system, with the same results. We encountered no difficulty in utilizing any disk containing HSFS data.

4.1.2 COTS MAGNETO-OPTICAL DISK

A COTS rewritable magneto-optical (MO) disk drive was obtained under this effort. Magneto-optical disks provide between 500 MB and 1 GB on a 5 1/4" form factor, and will soon store up to 10 GB on a 12-14" form factor. Although the read and write performance of MO storage has traditionally lagged far behind the performance of magnetic fixed disk systems, these limitations are rapidly being overcome. The Hewlett-Packard MO unit obtained under this effort has an average data access time of 19ms. This number compares favorably with many magnetic fixed disk units, which currently range between 8-20 ms. In addition, data transfer rates for MO disks are typically almost identical to those of magnetic disk. MO storage has a number of advantages over magnetic disk, including:

- √ **Long storage life** - Current MO disks are rated to maintain data integrity for 20 years
- √ **Durability** - MO disks are not affected by magnetic fields in the way magnetic disk are
- √ **Removability** - MO disk cartridges are small, and can be easily removed from the drive for storage or transport
- √ **Cost** - The cost for MO storage is approximately 20 cents per megabyte, as compared to approximately 1 dollar per megabyte for magnetic storage
- √ **Jukebox capability** - Because of their small size and removability, MO disks lend themselves well to jukebox applications in which a large number of disks is available in near-line storage

The majority of commercial MO disks utilize a polycarbonate plastics substrate, although several vendors have chosen to utilize glass. On a glass substrate a layer of photopolymer, stamped with servo tracks and other formatting marks, is laid down. On polycarbonate disks, these features are typically formed through an injection-molding process.

Above the grooves are three to four additional layers of material. One layer is the active recording material, which generally consists of a rare earth alloy such as terbium iron cobalt. The active recording layer is sandwiched between layers of a transparent dielectric medium which provides polarization enhancement as well as serving as a protective jacket for the recording layer.

The recording layer of the MO disk is magnetic, and rotates reflected polarized light in a phenomenon known as the Kerr effect. Prior to use a disk has a spatially uniform magnetization,

representing zeros at all bit positions. To write a binary one to the disk, a laser is focused on the domain, which rapidly raises the temperature of the magnetic layer to near the Curie point. Simultaneously, a small magnet on the opposite side of the disk imparts a field opposite to that of the original magnetization at that point, or domain. Once the laser is turned off, the domain quickly cools, taking on the polarity of the field imparted by the external magnet. Erasing a domain is performed by the same process, but with the polarity of the magnetic field reversed. All domains must be erased prior to writing, which generally results in very poor performance of an MO system during writing. Reads, which don't suffer from this handicap, are performed twice as fast.

To read from an MO disk, a weak laser with a linearly polarized beam is focused on the recording layer of the disk. Due to the Kerr effect, the reflected beam is rotated slightly in either a clockwise or counter-clockwise direction. Although the amount of rotation is very small, typically only a couple of degrees, the direction of this rotation can be measured. The direction of rotation indicates either a one or a zero in that domain.

MO disk drives are generally single sided. As a result, only half of the capacity of an MO cartridge is available for use at any one time. Thus, on a 500 MB disk, only 250 MB of storage is available to the user. In order to access the addition 250 MB of storage, the disk must be physically removed from the drive, and flipped over. The drive obtained under this effort was a 1 GB drive, thus allowing access to 500 MB of storage at any one time.

4.1.3 AIR FORCE STRATEGIC / TACTICAL OPTICAL DISK SYSTEM

The final system evaluated under this effort was the Air Force Strategic/Tactical Optical Disk System. The S/TODS is a large format (14") ruggedized MO disk with a capacity of 12 GB per platter, with 6 GB per side. The current S/TODS is a single sided drive, allowing access to 6 GB of storage at one time. As in most MO systems, the platter must be physically removed from the drive, and flipped over, in order to gain access to the second side. Unlike may MO systems which utilize a small sector size of 512 or 1024 KB, the S/TODS uses a sector size of 10764 bytes. The S/TODS was implemented in this fashion in order to allow for very high performance during reading and writing of real-time sensor data.

The S/TODS has been developed to operate in a modified MIL-E-5400 environment. The system has been designed for use in Scientific and Technical aircraft and Intelligence and Reconnaissance ground collection stations. The unit has demonstrated flight capability with tests on an RC-135 aircraft.

4.2 IDENTIFY AND ASSEMBLE SOFTWARE / DATA SUITE

4.2.1 OMM-IP

The OMM Image Processor (OMM-IP) is a TIFF format image viewer developed to time file data transfer rates. This package will display most available TIFF format images including bitmap (one color), 8-bit color, and 24/32-bit color images. The image display engine makes use of functions used in the shareware software packages *xtiff* and *xv*..

The primary function of the OMM-IP is to calculate file data transfer rates based on the time needed to load TIFF images into memory from a file and then display this information in the Statistical Information Window. These timing values only account for the actual access time, time used to convert the image to a displayable format or to shrink the image are not included in the calculation.

The OMM-IP can be run in two modes: Single Display Mode or Sequential Display Mode. When the OMM-IP is in Single Display Mode, the user may display images simply by selecting them from the list of available images and displaying them. This is the default mode. The OMM-IP can also be run in Sequential Display Mode. When in this mode, the OMM-IP will sequentially retrieve and display each image in the working directory. The Statistical Information Window will display the current total retrieval time and the average retrieval time per image.

4.2.1.1 Data Sources

The OMM-IP can utilize any standard TIFF-formatted image as input. If several images are to be displayed in succession, in Sequential Display Mode, they must all be present in the same directory. The OMM-IP will cycle through the directory, displaying all available TIFF images in alphabetic order by filename.

A number of TIFF data sources were utilized under this effort. The first, and most frequently used, source was the Jane's Electronic Information System, described in Section 4.2.3. This CD-ROM contains several hundred gray-scale images with sizes generally in the 512x512 pixel range. File sizes varied from 248K to 273K, and averaged approximately 263K. Because of their small size, these images were used extensively during software development for testing purposes. They were also used extensively during the software demonstration when a large number of images were to be displayed very rapidly. The gray-scale images require minimal processing by the OMM-IP, allowing them to be displayed very quickly. These images were chosen due to the fact that they are smaller than the sector size on the S/TODS, allowing us to evaluate it's performance when the sectors are highly fragmented.

The second source of TIFF imagery used under this effort was a commercial CD-ROM containing 112 high resolution color images. Each image was digitized in 24-bit color at a resolution of 300 dots-per-inch (300 dpi), resulting in images with average sizes of 5-6 megabytes each. Due to their extremely large size, the display time for the images on this CD-ROM was significantly higher than that for the gray-scale imagery. This image source was chosen due to the fact that the large files are significantly larger than the sector size on the S/TODS, allowing us to evaluate its performance when files span multiple sectors.

4.2.1.2 Measurements

The OMM-IP application was designed specifically to measure data transfer rates for medium to large files. For reasons of portability and software reuse, files are accessed through the standard Unix stream functions. Timing begins after the file is successfully opened, and ends when the last byte of the file is successfully read and returned to the calling program. All timings are performed in terms of milliseconds.

4.2.1.3 Results

Because all file I/O was performed through standard Unix file handling functions, it was found that the operating system introduced a bias in the results, as well as increasing the standard deviation of the results. This conclusion was reached by observing the results generated by multiple runs of several hundred images of varying size which were stored on fixed disk, MO,

and CD-ROM. It was found that the average transfer time between files fluctuated widely even when no other applications or users were present on the system. Averages did not settle into a "steady state" until 350-400 images had been read. We believe that this observation is tied directly to contention for both the bus and the processor by the Unix operating system's various housekeeping processes.

It was also found that the operating system was introducing a bias in the results which manifested itself in the form of data transfer rates which were significantly below the theoretical rates achievable by the storage systems and the system bus. We believe the typical degradation to be in the range of 20%. We attribute this to a number of factors. On most of the devices evaluated, a large part of the degradation can be attributed to inefficiency in the operating system's handling of the bus, and inefficiency in the device drivers which the operating system uses to manipulate the storage systems.

On the MO disk, an additional factor was present. The high capacity (1 GB) disks which we utilized under this effort use a sector size of 1024 bytes. The Sun operating system is only capable of handling sector sizes of 512 bytes in a native fashion. For this reason an additional device driver had to be installed to handle the translation and mapping of sector sizes. Although we had originally believed that this would adversely affect the data access and data transfer rates, this turned out not to be the case. As the results below indicate, the MO disk was roughly equal in performance to the fixed magnetic disk. However, when the MO disk is accessed through the additional driver, the I/O performance of all other applications present on the system becomes extremely poor. We believe that the driver maintains I/O performance on the storage device and bus by almost totally monopolizing the system CPU for sector translation processing.

The table below gives the results that were obtained from the OMM-IP application:

Device	Avg File Size (bytes)	# Images	Avg Retrieval Time (ms)	Standard Deviation
Winchester	55967	300	890.83	51.18
CD-ROM	55967	300	1004.71	46.37
MO	55967	300	960.33	49.29
Winchester	4158892	300	960.16	43.14
CD-ROM	4158892	300	978.77	48.44
MO	4158892	300	948.24	41.29

4.2.2 OMMAPS

The OMM ADRx Processing System (APS) is an imagery display and processing system developed by Synectics Corporation that can be used to interactively view selected areas of an arbitrarily large imagery database and report data access times for retrieving the required imagery. This application runs on a Sun SPARCStation and employs a Motif-based Graphical User Interface (GUI). The OMMAPS has been designed to use ARC Digital Raster Imagery (ADRI) / ARC Digital Raster Graphics (ADRG) data distributions. Distributions may be linked together to form what appears to be arbitrarily large distributions and can be processed as such.

4.2.2.1 Data Sources

The OMMAPS application can read, and display a number of standard Defense Mapping Agency (DMA) raster spatial data products:

- √ ARC Digital Raster Imagery (ADRI) produced from SPOT Panchromatic imagery at a resolution of 10m

- √ ARC Digital Raster Graphics (ADRG) at the 1:50,000 Operation Navigation Chart (ONC) level

- √ ARC Digital Raster Graphics (ADRG) at the 1:1,000,000 Joint Navigation Chart (JNC) level

Under this effort, a database of these spatial data products was assembled for use by the OMMAPS application. This database, as well as the nature of the ADRI and ADRG products, is described in Sections 4.2.4 and 4.2.5.

4.2.2.2 Measurements

The OMMAPS application measures the time required to retrieve a large number of very small (512x512 byte) image tiles on a random access basis. Unlike the OMM-IP application, which retrieves large amounts of data which are likely to be located contiguously on the disk, OMMAPS retrieves data which may be widely scattered in small pieces. Time measurement takes into account the time needed to retrieve the tile once it is located on the disk.

4.2.2.3 Results

As in the OMM-IP application, the OMMAPS application performs all file I/O through the standard Unix file handling functions. As a result, we noted in the OMMAPS application the same effects on I/O performance as was noted for the OMM-IP application. In particular, it was found that the operating system introduced a bias in the results, as well as increasing the standard deviation of the results. The performance degradation noted in the OMMAPS application was consistent in its magnitude with that noted in the OMM-IP application.

The table below gives the results that were obtained from the OMMAPS application:

Device	Data Type	Tile Size (bytes)	Avg Retrieval Time (ms)	Standard Deviation
Winchester	ADRI	262144	35.11	2.12
MO	ADRI	262144	37.28	1.39
Winchester	ADRG (JNC)	262144	57.12	2.47
CD-ROM	ADRG (JNC)	262144	59.86	2.81
MO	ADRG (JNC)	262144	57.59	1.17

4.2.3 JANES EIS

The Jane's Electronic Information System was obtained as a means of providing a qualitative measure of random access performance on all the storage devices evaluated under this effort. The Jane's EIS is a database, delivered on CD-ROM, which provides graphic and textual data on a wide number of weapons, aircraft, and naval craft. The disk also contains a search editor which can be used for locating information on a specific topic.

The Jane's EIS search application must be installed to a hard disk or MO disk before it can be run. The database itself my remain on the CD-ROM, or may also be copied to the hard disk or MO disk. This allows the random access performance of all devices evaluated under this effort to be evaluated.

Because the source code for the Jane's application is not available, there was no means of inserting a performance timing capability into the software. For this reason, Jane's is used exclusively for qualitative demonstration and evaluation, and no specific performance measures are available.

4.2.4 ADRI DATABASE

Under this effort a database of ARC Digital Raster Imagery was assembled to support the OMMAPS application. ARC Digital Raster Imagery, or ADRI, is a geocoded imagery product produced from commercial satellite imagery produced by the French SPOT satellite.

The imagery utilized by the ADRI product is SPOT panchromatic imagery having a pixel ground sample distance of 10 meters. Because it is panchromatic imagery, it consists of monochrome pixels having intensity values between 0 and 255.

Any imagery collected from an aerial point source, whether it be from a plane or a satellite, contains a number of distortions. The first, perspective distortion, causes all feature not located directly under the camera to appear as if they are displaced slightly outward toward the edge of the image. The further the feature is from the point directly under the camera, or nadir, the greater the magnitude of displacement. The displacement is directly proportional to the distance of the image feature from the nadir.

Terrain distortion does not have this proportional relationship. Terrain distortion is a special case of perspective distortion. Terrain distortion is a variable magnitude perspective distortion which is introduced by the varying height of features within the image. The taller an

object, the closer it is to the camera, and the greater the apparent displacement toward the edge of the image.

The final source of distortion results from the characteristics of the sensor itself. The camera, or sensor, lens introduces a characteristic distortion into the collected image. This distortion is also variable, and may often vary from one camera to another. For any precise mapping application, the lens distortion must be carefully determined for each individual lens so that the effect of the lens distortion on the collected imagery can be taken into account during measurement from the image.

All of these sources of distortion, taken together, can make it extremely difficult to make precise measurements of the location of features within the image. ARC Digital Raster Imagery does not suffer from this problem. In the production of ADRI, the digital imagery is processed to remove these distortions, and produce a digital "orthophoto". An orthophoto has the property of each pixel appearing as if it were viewed by the camera from directly above. This important characteristic gives an ADRI image the same properties as a map, allowing precise geographic coordinates to be measured directly from the image, and allowing multiple images to be tiled together to form a seamless image of the world.

The ADRI product places these digital orthophotos into a multi-file data structure that allows "tiles" of ADRI imagery to be retrieved on a random access basis, based on geographic coordinates. Each tile contains 512x512 pixels of imagery.

The ADRI product is produced and distributed on low density 8mm magnetic tape in 1 degree by 1 degree geocells. The low density 8mm format allows up to 2.5 GB of data to be placed on a single tape. This format was chosen over CD-ROM because of its very high storage density. The shear magnitude of data required to cover a 1 degree geocell at a resolution of 10m dictates that at most latitudes it would not be possible to fit even a single geocell on a 500 MB CD-ROM. The downside to the 8mm format is that the ADRI can not be directly utilized without first off loading the data to a random access device such as a hard disk or MO disk. This process can be very time consuming, requiring several hours to load a single tape. Once loaded the data from a single tape can easily fill several hard disks. This problem will be addressed by the Defense Mapping Agency in the near future, through the release of the Controlled Image Base (CIB). CIB will consist of imagery in much the same format as ADRI, but compressed and distributed on CD-ROM. CIB will also be National Imagery Transmission Format (NITF) compliant, allowing easier exploitation from a larger number of COTS and GOTS applications.

For this effort, a database of ADRI over a number of political "hot spots" was assembled. The total volume of data assembled was approximately 10 GB. Plots showing the geographic coverage of the database are given in Appendix C.

4.2.5 ADRG DATABASE

Under this effort a database of ARC Digital Raster Graphics was assembled to support the OMMAPS application. ARC Digital Raster Graphics, or ADRG, are color digital maps, at various map scales, produces by the DMA on CD-ROM.

The imagery utilized by the ADRG product is produced by scanning hardcopy maps in 24-bit color. Each pixel contains 8 bits of red, 8 bits of green, and 8 bits of blue.

Once scanned, ADRG is processed to place it into the same data structure as the ADRI product. As a result, the ADRG can also be retrieved, on a tile-by-tile basis, based on

geographic coordinates. Unlike ADRI, the ADRG product is not produced in a 1 degree by 1 degree geocell format. Each map scale uses different production standards, resulting in ADRG distributions at different scales which can not be easily registered to each other, or to an ADRI data set.

Because it is produced and distributed on CD-ROM, ADRG can be directly exploited without first being transferred to another device.

The OMMAPS application has been designed to utilize ADRG at the 1:50,000 Operation Navigation Chart (ONC) and 1:1,000,000 Joint Navigation Chart (JNC) levels. A database of ONC and JNC data was assembled under this effort to support the OMMAPS application. Plots showing the coverage of the database are given in Appendix D.

4.3 S/TODS - SUN INTEGRATION

The purpose of the S/TODS - Sun integration task was to provide an off-the-shelf Sun workstation with access to a single disk containing a single 6 GB file system.

As was discussed earlier in this report, there are two ways in which the S/TODS could be integrated with the Sun workstation. The first, writing a block device driver for the Sun workstation, would have allowed the S/TODS to be utilized on any Sun workstation running the SunOS 4.1.x operating system. This was the technical approach initially proposed for this effort.

However, after extensive discussions with the technical support and product development teams at Sun it was decided that an alternative approach should be followed. Under this approach a programmable SCSI controller was utilized to allow the S/TODS to emulate a standard SCSI device. This approach resulted in a number of advantages:

√ **Portability** - The resulting storage device can be utilized on any system which is capable of supporting a standard SCSI device. These systems include, amongst others, workstations from Sun, HP, DEC, Data General, Silicon Graphics, and personal computers from IBM and Apple.

√ **Cost** - The cost of integration through the use of a programmable SCSI control should have resulted in a lower cost and lower risk integration effort.

√ **Performance** - It was believed that the performance of the resulting unit would be higher with a controller-based solution than it would be in a block device driver solution.

The initial integration of the S/TODS resulted in a unit with extremely poor performance. Although the S/TODS is theoretically capable of sustained data transfer of 3 MB per second, the initial integration resulted in a unit which was only capable of a sustained data transfer rate of approximately 700 KB/sec. Analysis of the unit indicated that the problem could be rectified through the addition of several megabytes of cache memory, which would allow a small number of very large writes to be performed, as opposed to a large number of small writes.

During the integration it was also discovered that the SunOS 4.1.x operating system imposes limits on the size of a file system. Although the original intent of the integration effort was to provide a single file system of 6 GB, we discovered that the SunOS operating system

limits the size of a single file system, and the size of a single file, to 2 GB. Further investigation revealed that this is a limit imposed by any Unix operating system which is based on the AT&T System V or BSD standards. The limitation arises from the size of a fixed width field, in the file system standard, which is used to store the number of bytes making up the file system.

Under the Sun Solaris 2.x operating system, or any other operating system based on the new System V Release 4.2 (SVR4.2) Unix standard, this limitation will be removed. However, the hard file size limit of 2 GB will remain.

Following the addition of the cache memory, performance seemed to improve. The unit was packed and shipped to Rome Laboratory for demonstration, evaluation, and data loading. The intent was to load the entire ADRI and ADRG databases to S/TODS platters. During this loading process additional problems were discovered. The S/TODS performed very well during the first data transfer of each session. However, during subsequent data transfers the sustained data transfer performance dropped dramatically to an unusable level. As a result, we were unable to load the ADRI and ADRG databases to the S/TODS. In an attempt to quantify the level of performance being achieved, we performed a number of tests in which a large fixed size file was transferred from the system hard disk to the S/TODS, and from the system hard disk to the COTS MO disk drive which was obtained under this effort. The time required to perform each transfer was recorded. The resulting performance figures are given below:

File Size (bytes)	Source Device	Destination Device	Start Time (hr:min:sec)	End Time (hr:min:sec)	Elapsed Time (hr:min:sec)
31408128	Winchester	MO	09:17:11	09:17:58	00:00:47
31408128	Winchester	S/TODS	09:19:38	09:38:12	00:18:34
31408128	S/TODS	Winchester	10:00:07	10:06:35	00:06:28
31408128	MO	Winchester	09:58:02	09:58:46	00:00:44
31408128	Winchester	S/TODS	10:11:58	10:30:41	00:18:49

These tests were performed reading and writing directly to S/TODS Disk #13, Side 2, Partition 1, with the file system at 4% capacity. The partition was mounted directly on the /tods1/omm mount point. The file path depth had no measurable effect on performance.

The final problem encountered with the integration of the S/TODS with the Sun workstation was data corruption. When first delivered to Rome Laboratory and installed on the Sun workstation, the S/TODS was exhibiting data corruption problems when writing data to the S/TODS. This problem was traced to interference in the unshielded data cable. The problem was corrected on the spot by rerouting the data cable away from RF sources. Afterward, a shielded data cable was produced in order to prevent problems in the future.

Because of the data transfer and data corruption problems which were observed, the S/TODS was repackaged and shipped back to Martin-Marietta in Camden, NJ, for further development and refinement following the conclusion of the OMM ATD effort.

4.4 DEMONSTRATION

At the conclusion of the OMM ATD effort, the S/TODS and HP magneto-optical disk drives were delivered to Rome Laboratory and installed on a Sun SparcStation 2 workstation for demonstration and evaluation. A CD-ROM drive was provided by Synectics for the evaluation.

The OMMAPS and OMMIP applications were installed on the SparcStation and demonstrated with the ADRI and ADRG data resident on the MO drive.

5.0 RECOMMENDATIONS AND LESSONS LEARNED

This effort resulted in a number of recommendations and lessons learned. These are summarized below:

√ **Improvements need to be made to the S/TODS** - The poor performance of the S/TODS indicates that further improvements need to be made. The S/TODS is theoretically capable of sustained data transfer of 3 MB/sec. Under this effort, the S/TODS was only capable of performing at modem speeds. Since the conclusion of the effort Martin-Marietta has made a number of enhancements to the S/TODS which have allowed it to perform at roughly the same rate as the COTS magneto-optical disk used in the OMM ATD effort. The write time for the 31 MB file used during our evaluation has been reduced from 18 minutes to approximately 1.5 minutes. Read times for the same file have been reduced from 6 minutes to approximately 1 minute. If the S/TODS is to be used for recording real-time sensor data on a file system such performance is still insufficient. However, given the 2 GB file size limit imposed by the Unix operating system, we must question whether or not real-time data should be recorded in a file system, or if such data should be recorded in a raw device mode where the S/TODS has already proven itself capable of living up to its performance promises.

√ **Benchmarking run under Unix can lie** - The variations in I/O performance that we observed lead to the conclusion that any benchmarks run under a complex operating system such as Unix must be evaluated very carefully. A single benchmark, such as I/O performance, can not be evaluated in isolation. A Unix system contains such a wide range of variables that any number of factors can impact on measured performance. In order to get a clear picture of total system performance it is necessary to measure the performance of a number of subsystems, including the CPU, the bus, the network, and graphics. Under any follow-on effort, the performance measurement capabilities of this prototype testbed should be expanded to examine additional system variables. It will also be important to identify benchmarks which can get closer to the actual hardware, thus reducing the impact of such variables as the operating system on the measured performance.

√ **High raw device performance does not necessarily translate into high file system performance** - Because of processing overhead imposed by the operating system, and data structuring overhead imposed by a file system, the performance of a high performance storage device can be severely impacted. This phenomenon was observed rather dramatically in the case of the S/TODS. This same phenomenon was observed in a slightly less dramatic fashion in the system performance impacts caused by the MO device driver when writing to the COTS MO disk. In light of this fact, and the fact that the size of a file or file system is limited, we must question the utility of a high performance storage device being used as a structured storage device for real-time applications such as reconnaissance data recording. It is likely that such devices are optimally applied to an environment in which the device can be operated in a raw mode, and in which the abilities of devices such as the S/TODS have been proven. For applications requiring a ruggedized file system device, such as

supporting a shelterized workstation, it may be necessary to accept less than optimal throughput for the advantages of having an extremely dependable file system device.

√ **There is a need for both qualitative and quantitative measures of performance** - Quantitative performance measures, such as the number of milliseconds required to retrieve a tile of ADRI or ADRG, have little practical meaning to the average user. The average user is interested only in the perceived delay encountered between requesting data and having data available for use. On the other hand, it is impossible to accurately compare multiple devices on a qualitative basis.

√ **There is a need for a more rigorous quantitative performance measurement capability** - Although the OMMAPS and OMMIP applications were sufficiently rigorous to provide us with extremely crucial performance data, we believe that this analytical capability must be expanded to include the ability to measure additional system parameters, and to measure the same system parameters with less interference from such factors as the operating system.

APPENDIX A OMM-IP USER'S MANUAL

A1.0 ABOUT THE OMM IMAGE PROCESSOR

The OMM Image Processor (OMM-IP) is a TIFF format image viewer developed to time file access rates. This package will display most available TIFF format images including bitmap (one color), 8-bit color, and 24/32-bit color images. The image display engine makes use of functions used in the shareware software packages *xtiff* and *xv*..

The primary function of the OMM-IP is to calculate file access rates based on the time needed to load TIFF images into memory from a file and then display this information in the Statistical Information Window. These timing values only account for the actual access time, time used to convert the image to a displayable format or to shrink the image are not included in the calculation.

The OMM-IP can be run in two modes: Single Display Mode or Sequential Display Mode. When the OMM-IP is in Single Display Mode, the user may display images simply by selecting them from the list of available images and displaying them. This is the default mode. The OMM-IP can also be run in Sequential Display Mode. When in this mode, the OMM-IP will sequentially retrieve and display each image in the working directory. The Statistical Information Window will display the current total retrieval time and the average retrieval time per image. The user may switch to Sequential Display Mode, pause the process, reset the process, or switch back to Single Display Mode at any time.

To run the OMM-IP, type *img_proc* at the UNIX prompt. The application will then begin to process by first listing the session parameters, run its internal initialization routines, and generating the OMM-IP display. The user can modify the system run parameters through the use of command line arguments. Exhibit A-1 lists the valid command line arguments. The underlined option indicates the system default.

Exhibit A-1 OMM-IP Command Line Arguments

Argument	Description
{<u>C_FAST</u> | C_SLOW | C_BEST}	Set the 24/32-bit image conversion routine. The system is only able to display 8-bit imagery, therefore 24- and 32- but images must first be converted to 8-bit images. Three conversion functions are available.
HELP	Display a description of the valid command line arguments.
{<u>SHR_ON</u> | SHR_OFF}	Turn the Auto-Shrink Option 'on' or 'off'. The auto-shrink option will automatically reduce an image by a factor of 0.5x when the image will not fit in the image display window.

A1.1 THE OMM-IP APPLICATION ENVIRONMENT

The following section provides a detailed look at the OMM-IP Application Environment. It begins by detailing some general information regarding the use of the Motif Colormap. This is followed by a general overview of the OMM-IP Display Interface as a whole, and then details on each of its components.

A1.1.1 OMM-IP COLORMAP PROCESSING

Since the OMM-IP is, by nature, an imagery processing system, it makes extensive use of the Motif Colormap. The colormap is the method by which Motif may alter the system Look Up Tables (LUTs) to define the colors used to display imagery. For reasons of speed and efficiency, the OMM-IP completely redefines the colormap that it uses during its processing. As a result, the colormap may be redefined each time a new image color scheme is encountered. This method of implementation has three noticeable consequences.

√ When the cursor is moved from one window to another there tends to be a 'flash' effect. This effect is normal and causes no harm to the OMM-IP or any other applications running on the workstation.

√ Due to the OMM-IP locally modifying the global display colormap, there tends to be a drastic alteration of the display characteristics of the applications that are not currently in control. The current controlling application's colors will always be correct as will any application in the background that uses the same colormap definition, all others may not. This again has no detrimental effects to any of the applications.

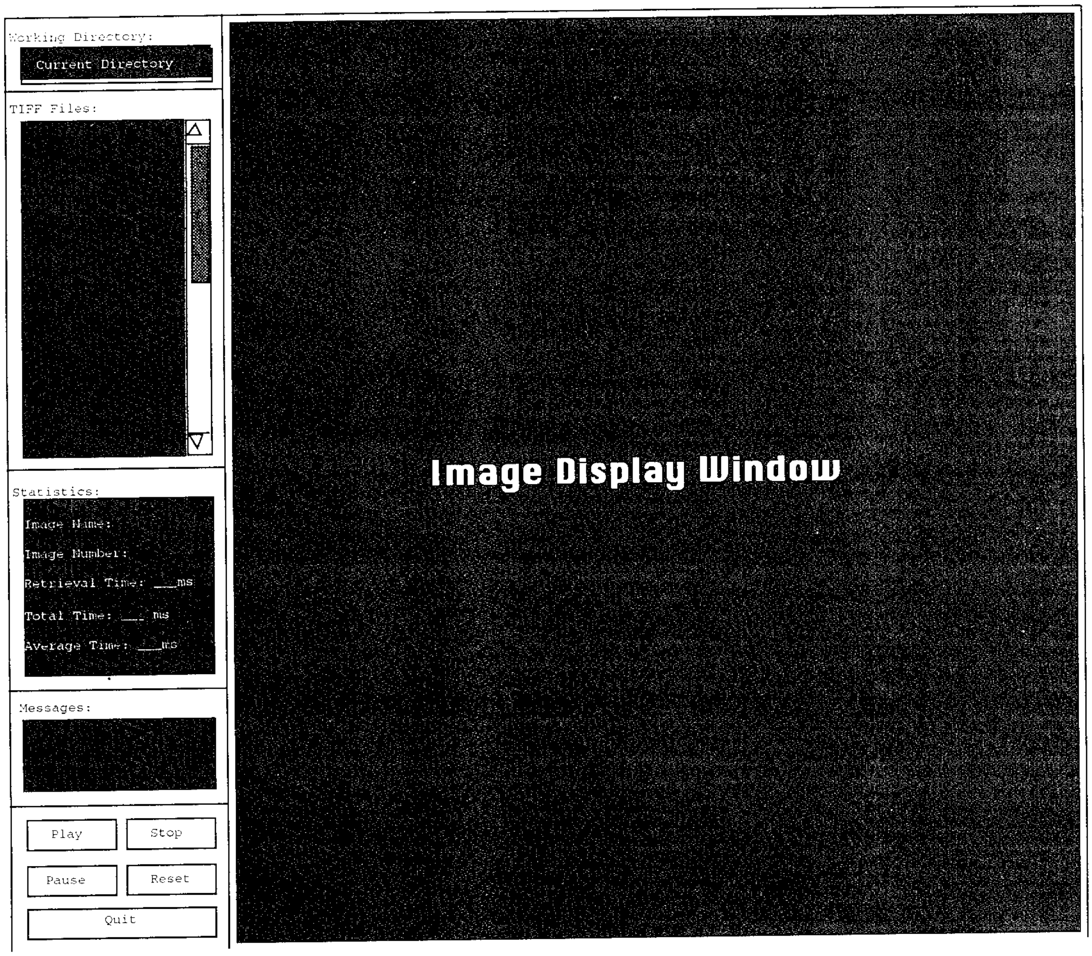
√ The OMM-IP display feature colors may be slightly modified with each new colormap representation. This is mostly apparent with respect to Motif item shadowing and the application border. The image displayed will not be affected, nor will the OMM-IP application processing.

A1.1.2 THE OMM-IP DISPLAY INTERFACE

The OMM-IP Display Interface is essentially a Motif application shell widget. As a result it appropriately processes all standard Motif application level events. This includes the iconify, move, and resize events among others. The main display is divided into two sections: The Image Display Window and The Control Panel (Exhibit A-2).

The OMM-IP, by default, uses the entire monitor display for its Display Interface. This helps to maintain readability and minimize the apparent effects of colormap manipulation. The user may resize the display manually but minimum size requirements are enforced. These minimum values are applied not only when the display interface is manually adjusted but also at system startup. If the OMM-IP is run and the monitor display is smaller than the minimum required size, the process will be aborted with the appropriate error message.

Exhibit A-2 OMM-IP Display Interface



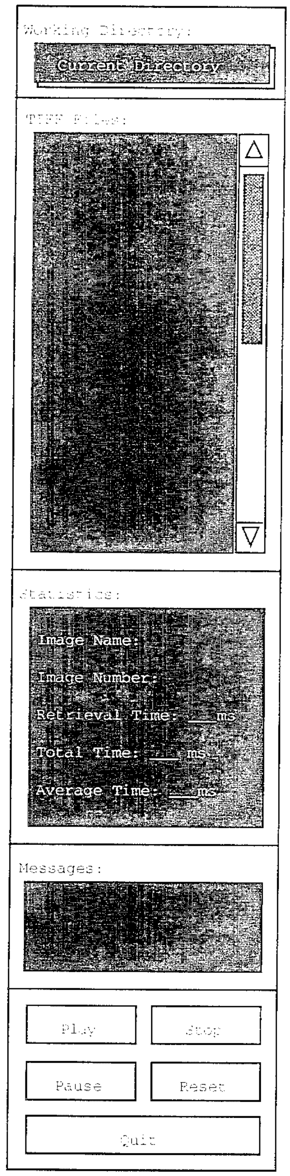
A1.1.3 THE IMAGE DISPLAY WINDOW

The Image Display Window is the area within the OMM-IP in which all TIFF images are displayed. Images are displayed starting in the upper left corner of the display and if it is larger than the display window, it will simply be clipped to fit it. The background color of the image window will vary based on the TIFF color content of the image being displayed.

A1.1.4 THE CONTROL PANEL

The Control Panel serves as the interface between the user and the OMM-IP and is itself divided into five (5) components (Exhibit A-3).

Exhibit A-3 Working Directory Options

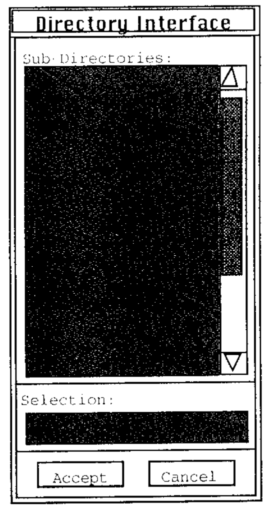


A1.1.4.1 Working Directory Section

The Working Directory Section consists of a single push button, labeled with the working directory path. This directory is where the available TIFF files are to be read from. The user

may change the current working directory by pressing this button which generates the Sub-Directory Menu Dialog (Exhibit A-4).

Exhibit A-4   Sub-Directory Menu Dialog



The sub-directory menu consists of a scrolled list of sub-directories, a text entry field, and a pair of control buttons. The user may either double-click one of the listed sub-directories, or explicitly enter a directory path in the selection field and press the *Accept* button. The new path, either relative or root, is verified and the working directory is updated accordingly. The user may cancel this process at any time by pressing the *Cancel* button.

<u>A1.1.4.2   TIFF Files List</u>

The TIFF File List Section of the Control Panel consists of a scrolled list of all the files in the working directory that have the *.tif* extension. The user can display any of the listed images simply double-clicking appropriate list item when the system is in Single Display Mode.

A1.1.4.3 Statistical Information Window

The Statistical Information Window section displays the timing statistics generated during OMM-IP processing. The following information is displayed:

- √ The Image Name
- √ The Image Sequential Display Number (= 1 in Single Display Mode)
- √ The Image Retrieval Time, in milliseconds.
- √ The Total Image Retrieval Time, in milliseconds. (= Image Retrieval Time in Single Display Mode)
- √ The Average Display Time, in milliseconds. (= Image Retrieval Time in Single Display Mode)

These values are updated every time an image is displayed regardless of the Display Mode.

A1.1.4.4 Message Window

The Message Window is used to inform the user of operation status. This includes information such as the stage of the image retrieval process or error conditions that occur.

A1.1.4.5 Process Control Section

The Process Control Section consists of a set of five (5) control buttons. The first four buttons (*Play, Stop, Pause, Reset)* are Sequential Display Mode controls. The final button in the Process Control Section is the *Quit* button which can be used to end the current OMM-IP session normally.

The Sequential Display Mode controls are used to initiate and control processing in the Sequential Display Mode. The user can enter this mode at any time simply by pressing the *Play* button. The system will then begin to sequentially display each image found in the current working directory, updating the statistical information after displaying each image. The user can suspend the display process by pressing the *Pause* button. This will stop the display process, but leave the system in Sequential Display Mode. The user can then reset the timing statistics, if so desired, by simply pressing the *Reset* button. The user can stop the display process and exit Sequential Display Mode by pressing the *Stop* button. Please note, the OMM-IP will finish displaying the image in process when either the *Pause* or *Stop* button is pressed.

APPENDIX B OMMAPS USER'S MANUAL

B1.0 ABOUT THE OMM ADRX PROCESSING SYSTEM

The OMM ADRx Processing System (APS) is an imagery display and processing system developed by Synectics Corporation that can be used to interactively view selected areas of an arbitrarily large imagery database and report data access times for retrieving the required imagery. This application runs on a Sun SPARCStation and employs a Motif-based Graphical User Interface (GUI). The OMMAPS has been designed to use ARC Digital Raster Imagery (ADRI) / ARC Digital Raster Graphics (ADRG) data distributions. Distributions may be linked together to form what appears to be arbitrarily large distributions and can be processed as such.

B1.1 THE OMMAPS APPLICATION ENVIRONMENT

The following section provides a detailed look at the OMMAPS Application Environment. It begins by detailing some general information regarding the use of the Motif Colormap. This is followed by a general overview of the OMMAPS Display Interface as a whole and then details on each of its components.

B1.2 OMMAPS COLOR MAP PROCESSING

Since the OMMAPS is an imagery processing system, it makes extensive use of the Motif Colormap. The colormap is the method by which Motif may alter the system Look Up Tables (LUTs) to define the colors used to display imagery. For reasons of speed and efficiency, the OMMAPS completely redefines the colormap that it uses during its processing. In fact, since the system uses both ADRI and ADRG imagery data it actually rewrites the colormap in part as either gray scale or full color respectively whenever it switches between the two data types. This method of implementation has three noticeable consequences.

√ When the cursor is moved from one window to another there tends to be a 'flash' effect. This effect is normal and causes no harm to the OMMAPS or any other applications running on the workstation.

√ Due to the OMMAPS locally modifying the global display colormap, there tends to be a drastic alteration of the display characteristics of the applications that are not currently in control. The current controlling application's colors will always be correct as will any application in the background that uses the same colormap definition, all others may not. This again has no detrimental effects to any of the applications.

√ Depending on whether you are currently displaying ADRG or ADRI imagery data, the border surrounding the Application and any OMMAPS dialog windows may vary. This causes no harm and does not effect the Motif window functions.

B1.3 THE OMMAPS DISPLAY INTERFACE

The OMMAPS Display Interface is essentially a Motif application shell widget. It has all the window controls any Motif application widget has. This includes the abilities to be iconified, moved, and resized among others.

The major window components are incorporated within one main application window. Due to the size of the component parts, the OMMAPS will verify at startup that the current display monitor meets the minimum size requirements. If the monitor display is not large enough, the OMMAPS will abort with the appropriate message. The OMMAPS desktop environment has been designed to initialize itself to the full size of the display. There are two main reasons for doing this. First, due to the size of the component parts of the application display, the larger the application window, the more readable the display is. The second reason refers back to the above discussion on the colormap. By making the OMMAPS application take up the entire display screen, it makes the effects of the colormap changes less evident. In particular, the effects of locally modifying the colormap are less noticeable.

The OMMAPS application work area is divided into five (5) primary areas each of which is indicated in the following diagram (see Exhibit B-1).

√ The Menubar

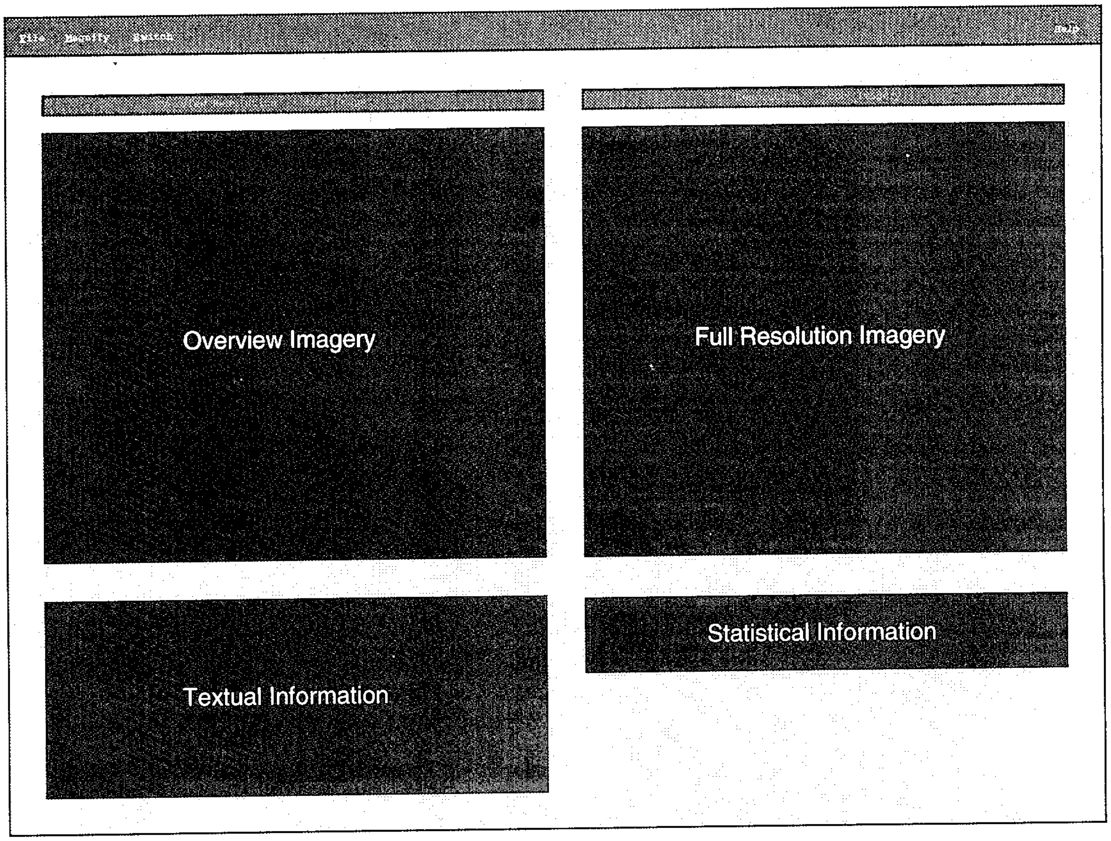
√ The Overview Image Window

√ The Full Resolution Image Window

√ The Textual Information Window

√ The Statistical Information Window

Exhibit B-1 OMMAPS Display Interface



B1.3.1 THE MENUBAR

The Menubar serves as the user's means of controlling the operation of the OMMAPS. All OMMAPS functions are accessed via the menubar, with the exception of those found on the pointer button controls. The Menubar itself is found along the top of the application window. It can be accessed directly via the system pointer or it may also be accessed via the keyboard. When using the keyboard to access the menubar options, the operator will use the following keystroke convention:

'◊' + <hot character>

The 'hot character' for each menu item is indicated in the menu option's name by an underscore. Once a menubar item is chosen, any menu option under that menubar item may be accessed by scrolling through the available items using the arrow keys or pressing the key corresponding to the option's 'hot character'.

The menubar contains four (4) elements that are displayed at all times: *File, Magnify, Switch,* and *Help*. In keeping with Motif standards, the menubar (as well as all other dialogs) contains a *Help* button. The OMMAPS Help facility has not, however, been implemented. As a result, this and all other 'Help' buttons are currently set to 'insensitive' and can not be used.

B1.3.2 THE IMAGE OVERVIEW WINDOW

The Overview Image Window is used to display a lower resolution imagery area that will serve as a frame of reference for the operator. This window is found on the left side of the display. Above the Overview window is a title bar that will indicate which window it is and what type of imagery data is being displayed.

At the center of the Overview Image Window will be a red square. This red square indicates the area represented in the Full Resolution Image Window. During the magnification process, this square will be shrunk in size to represent the smaller area displayed in the Full Resolution Image Window. A smaller red square containing a red dot in its center may also be found in the Overview Image Window, this is the Reference Point Indicator. As its name implies, this represents the current point of reference in the OMMAPS.

B1.3.3 THE FULL RESOLUTION IMAGE WINDOW

The Full Resolution Image Window serves to display the current imagery data at its full resolution and it is found on the right side of the display. Above the Full Resolution window is a title bar that will indicate which window it is and what type of imagery data is being displayed. A small red square containing a red dot in its center may be found in the Full Resolution Image Window, this is the Reference Point Indicator. As its name implies, this represents the current point of reference in the OMMAPS.

B1.3.4 THE TEXTUAL INFORMATION WINDOW

The Textual Information Window is found in the lower left portion of the display and it serves two purposes. The primary function of this window is to relate information regarding the current state of the OMMAPS system. At any given time during normal processing, this window will display the name of the AOI in process and information concerning the current point of reference such as its location and elevation along with additional information (see Exhibit B-2).

Exhibit B-2 The Textual Information Window Display

Current AOI: ________________________________
Point Identifier = ________________________________
COORDINATES (WGS-84)
Latitude = ___.________ Decimal Degrees
Longitude = ___.________ Decimal Degrees
Elevation = _____ Feet (Mean See Level)
Full Resolution Magnification Factor = __x
Error Estimates (0 indicates unknown)
Absolute 90% CE, LE = __,__ Meters
Relative 90% CE, LE = __,__ Meters

The Textual Information Window also serves as a means by which the OMMAPS can communicate with the operator. In particular, during the Area of Interest (AOI) Load Process this window is used to display what stage the load process is in.

B1.3.5 THE STATISTICAL INFORMATION WINDOW

The Statistical Information Window is found in the lower right portion of the display. Its function is to relate the average time to retrieve an imagery tile and the total time necessary to retrieve the entire image. The information in this window is updated every time imagery data is retrieved and it relates only to the time needed to retrieve the imagery data from whatever media it is stored on. The time X and Motif use to display the imagery is ignored. Exhibit B-3 displays the structure of the Statistical Information Window.

Exhibit B-3 The Statistical Information Window Display

File Retrieval Statistics --
Average Retrieval Time: ___.___ ms
Total Retrieval Time: ______ ms

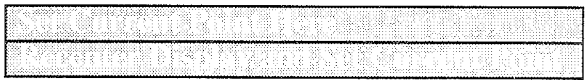
B1.3.6 POINTER DEVICE CONTROLS

A key tool used by the OMMAPS is the pointer device attached to the Sun SPARCStation. The OMMAPS expects the system to have a standard 3-button pointer device, such as a mouse or a trackball, attached to it. As with all Graphical User Interface (GUI) systems, the pointer is the primary method by which the process flow is controlled. All aspects of the OMMAPS can be controlled using a 'point & click' approach. For convenience, a number of functions have been directly tied to each of the pointer buttons and are available when the pointer is used <u>within</u> either of the Image Windows.

<u>B1.3.6.1 Left Button Options</u>

The controls associated with the left button are intuitive point processing tools. While within either image window the cursor arrow is replaced by a crosshair. Each of these functions bases its processing on the point found under the crosshair when the left button is pressed. Pressing and holding the left button will popup the following two option menu.

Exhibit B-4 Left Button Options Menu



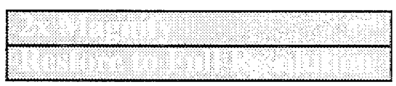
The first option, 'Set Current Point', resets the current system reference point to be the selected point. As a result of this, the geographic information regarding the point will be displayed in the Textual Information Window and the imagery data will be redisplayed with the Reference Point Indicator repositioned accordingly.

The second option, 'Recenter on Current Point', does just what its name implies. It recenters both the Overview and Full resolution windows on the selected point. It also resets the system reference point to correspond with the new center point.

B1.3.6.2 Middle Button Options

Unlike the Left Button Options, the controls associated with the middle button are not point specific but rather convenience functions. Pressing and releasing the middle button generates the 2-option magnification menu (see Exhbit B-5). This menu contains the same magnification options as those found under the *Magnify* button on the menubar.

Exhibit B-5 Center Button Options Menu



The first option, '2x Magnify', will perform a pixel replication magnification of the image found in the Full Resolution Image Window. The second option, 'Restore to Full Resolution', restores the image in the Full Resolution Image Window to normal. See the section on the *Magnification Options* for more information concerning the magnification process.

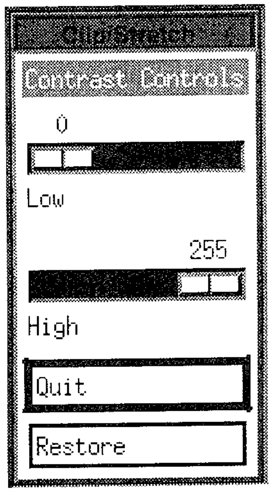
B1.3.6.3 Right Button Options

As with the Center Button Options, the function associated with the right button is not associated with the point found under the crosshair, but rather, is a convenience function. When the right button is pressed and released, the Contrast Control Dialog is generated* (see Exhibit B-6).

The Contrast Control is tool that can be used to improve the readability of the ADRI display imagery. The user may use the slide controls to set the highest and the lowest pixel values to be displayed. The system then 'clips' and 'stretches' the colormap based on these new values. This is a dynamic process and the results are immediately evident while the slider is being dragged. The colormap may be reset to its original values at anytime by pressing the 'Restore' button in the Contrast Control dialog. The Contrast Controls may also be used on ADRG imagery, but the effects are erratic and no real use.

* Due to assignments already linked to the Third Pointer Button by Motif, there is a pause between the time the button is released and the Contrast Control Dialog is displayed. This will be corrected in future DIVS releases, but for now it is asked that the operator simply be patient when using this function.

Exhibit B-6 Contrast Control Dialog



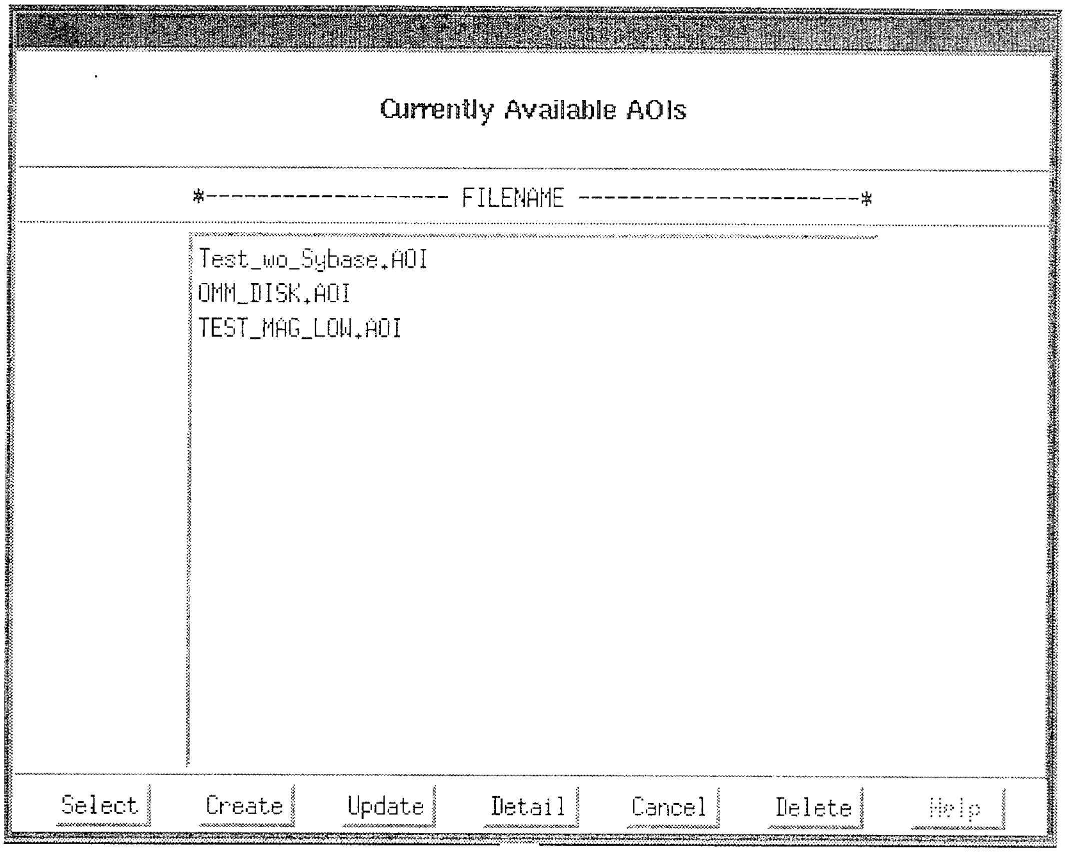
B1.3.7 FILE MENU OPTIONS

There are seven (7) selections found below the *File* option in the menubar and these comprise the system level controls for the OMMAPS.

B1.3.7.1 Select/Create Area of Interest

All processing within the OMMAPS takes place within the confines of an Area of Interest (AOI). The AOI structure is the means by which the user may link multiple distributions of various imagery types together and then save these configurations to a file for later use. Selecting this option initiates all the AOI processing functions available to the OMMAPS user. When selected, it brings up the AOI Selection List (see Exhibit B-7). This is the same dialog that is displayed at system startup. The AOI Selection List dialog consists of a scrolled list of the names of saved AOIs. Following the AOI list is a series of seven (7) control buttons that run along the bottom of the dialog. These buttons correspond to all of the AOI functions available to the user. The *Help* button associated with this dialog, as well as all other Help buttons, is insensitive and can not be used.

Exhibit B-7 Area of Interest Selection List



B1.3.7.1.1 Selecting an AOI

The OMMAPS user may select an Area of Interest to process by either double-clicking the desired AOI list item or highlighting the appropriate entry and pressing the *Select* button. Once an AOI is selected, the Selection List is automatically popped down. If an AOI was already loaded into the system when another is selected, the current AOI information is cleared. The system then opens the AOI file and begins the initialization process.

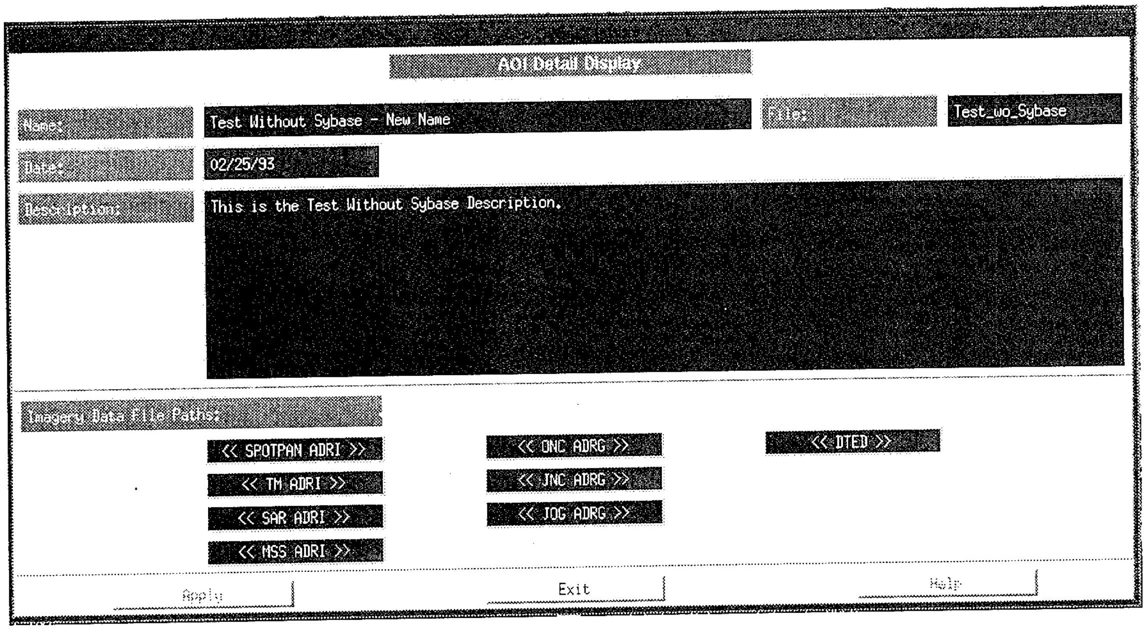
The AOI initialization process consists of the OMMAPS reading the AOI file and the various imagery header files for each set of imagery data files associated with the selected AOI. The necessary data is then stored in memory for fast access. The length of this process will vary depending on the size and content of the AOI being loaded. The Textual Information Window will indicate each step of the initialization process as it occurs. Any processing errors that occur will also be indicated. At the conclusion of this process, each window will be loaded with imagery and the Textual Information Window will be loaded with the data corresponding to the initial geographic coordinate which is arbitrarily chosen based on the imagery available. The application will choose the initial imagery display type to be the lowest resolution imagery present for the selected AOI. Once loaded, the AOI information will stay constant in the system memory. Any modifications to the AOI information file will not be applied to the current session without first re-loading the AOI.

If an error(s) occurs and, as a result, no imagery data is loaded for a particular AOI, the appropriate error message will be displayed. When the error message is cleared, the AOI Selection List will be redisplayed automatically.

B1.3.7.1.2 Creating an AOI

The AOI creation process is initiated by pressing the *Create* button on the AOI Selection List Dialog. This causes the AOI Detail Display to be brought up (see Exhibit B-8). The AOI Detail Display is broken up into two (2) sections. The first section contains overview information and the second serves as the interface between the AOI and the imagery header data files.

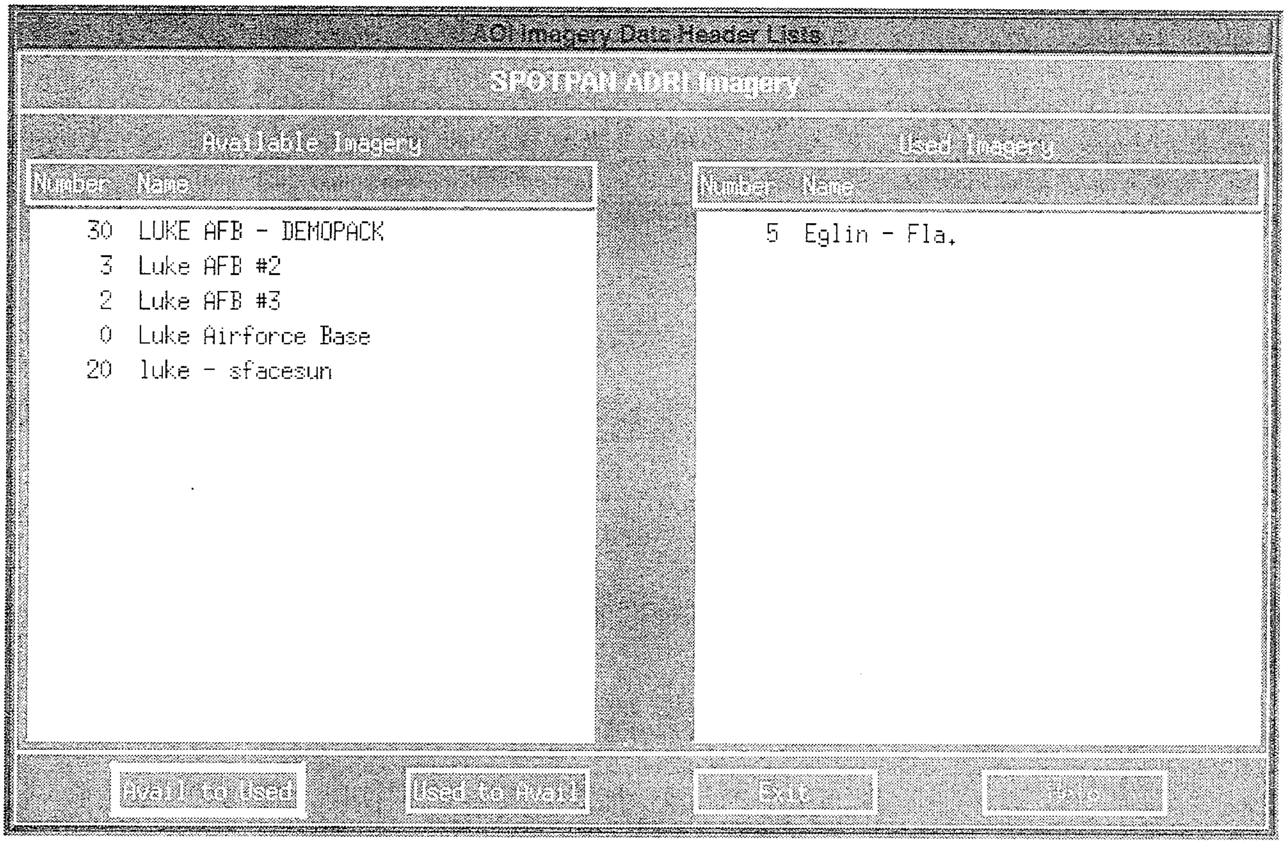
Exhibit B-8 AOI Detail Display



When creating an AOI, the operator must first enter the overview information and then select the imagery datasets to associate with it. The detail display window will be brought up with the date pre-loaded, which can not be modified. The operator must then load the AOI name, the AOI filename to associate it with, and a brief description.

Once the overview information has been entered, the operator chooses what imagery will be associated with the new AOI. To do this, the operator simply presses the button for the desired data type. This will cause the Imagery Association Dialog to be generated (see Figure 9). This dialog is made up of two scrolled lists and a set of control buttons. The list on the left reflects the available imagery distributions for the current image data type and the right will represent the imagery distributions associated with the new AOI and will initially be empty. In order to link an imagery distribution to the AOI, the operator may either double-click the item on the Available list or highlight it and press the *Avail to Used* button. Once selected, the item is moved from the Available list to the Used list. To remove an item from the Used list, the user may either double-click the item on the Used list or highlight it and press the *Used to Avail* button. The item is then moved from the Used list back on to the Available list. Once all the desired imagery distributions have been moved to the Used list, the operator presses the *Exit* button and returns to the AOI Detail Window. This process is repeated for each imagery type that is to be associated with the new AOI.

Exhibit B-9 Imagery Association Dialog



After all the information for the new AOI has been loaded, the user must explicitly save it by pressing the *Apply* button. Once the new AOI is saved, the AOI detail window will be popped down and the new AOI is added to the AOI Selection List. The new AOI is immediately available to be loaded to the OMMAPS. The operator can cancel the AOI creation process at any time by pressing the *Exit* button. If the new file has the same name as a previously existing AOI, the operator will be prompted to confirm the overwrite prior to its being performed.

B1.3.7.1.3 Updating an Existing AOI

The AOI update process is initiated by highlighting an AOI list item and pressing the *Update* button on the AOI Selection List Dialog. This causes the AOI Detail Display to be generated (see description under Creating an AOI). The operator can then update the overview information and/or the associated imagery.

Updates made to the overview section are limited to either the AOI name or description fields. Updates made to the imagery associated with the selected AOI are performed using the same method described in creating an AOI. The operator presses the button for the imagery type to process and then either moves items from the Available list to the Used list or visca-versa. This can either be done by double-clicking a list item or highlighting it and pressing the appropriate button. All updates must be explicitly saved by pressing the *Apply* button on the AOI Detail Display.

Updates can be applied to the AOI currently loaded to the OMMAPS system, however, any changes made will not effect the current OMMAPS session unless the AOI is reloaded. The AOI detail window may be popdown at any time by pressing the *Exit* button.

B1.3.7.1.4 Displaying an AOI

The AOI display process is initiated by highlighting an AOI list item and pressing the *Detail* button on the AOI Selection List Dialog. This causes the AOI Detail Display to be generated (see description under Creating an AOI). None of the AOI fields may be modified when the AOI dialog is brought up in Display Mode. The operator can see which imagery sets are linked to an AOI for each type of imagery by pressing the corresponding button. The detail window may be popdown at any time by pressing the *Exit* button.

B1.3.7.1.5 Exiting the AOI Selection List

When AOI Selection List processing is completed, the operator may popdown the AOI Selection List dialog directly by pressing the *Cancel* button.

B1.3.7.1.6 Deleting an AOI

The AOI delete process is initiated by highlighting an AOI list item and pressing the *Delete* button on the AOI Selection List Dialog. The operator will be prompted to confirm the deletion before it is performed. When the delete is completed, the AOI Selection List is redisplayed reflecting the update.

B1.3.7.2 Displaying The Current AOI

The user may display the AOI currently being processed by selecting the *Display Current AOI* option. This causes the AOI Detail Display to be generated (see description under Creating an AOI) loaded with the appropriate data. None of the AOI fields may be modified when the AOI dialog is brought up in Display Mode. The user can see which imagery sets are linked to an AOI for each type of imagery by pressing the corresponding button. The detail window may be popdown at any time by pressing the *Exit* button.

B1.3.7.3 Visit a Specific Geographic Coordinate

The *Visit Geo-Point* option allows the operator to input a specific geographic coordinate to recenter the reference imagery displays on. When this option is selected, a prompt dialog will be generated and the user will be instructed to enter the geographic location to be recentered on. These values should be entered in decimal format based upon the 1984 World Geodetic Survey (WGS-84) Standard. The entered coordinates are verified and if they are valid the imagery will be recentered on that position. The Textual Information Window data will then be updated to reflect the information corresponding to the new system reference point.

B1.3.7.4 Load Imagery Headers

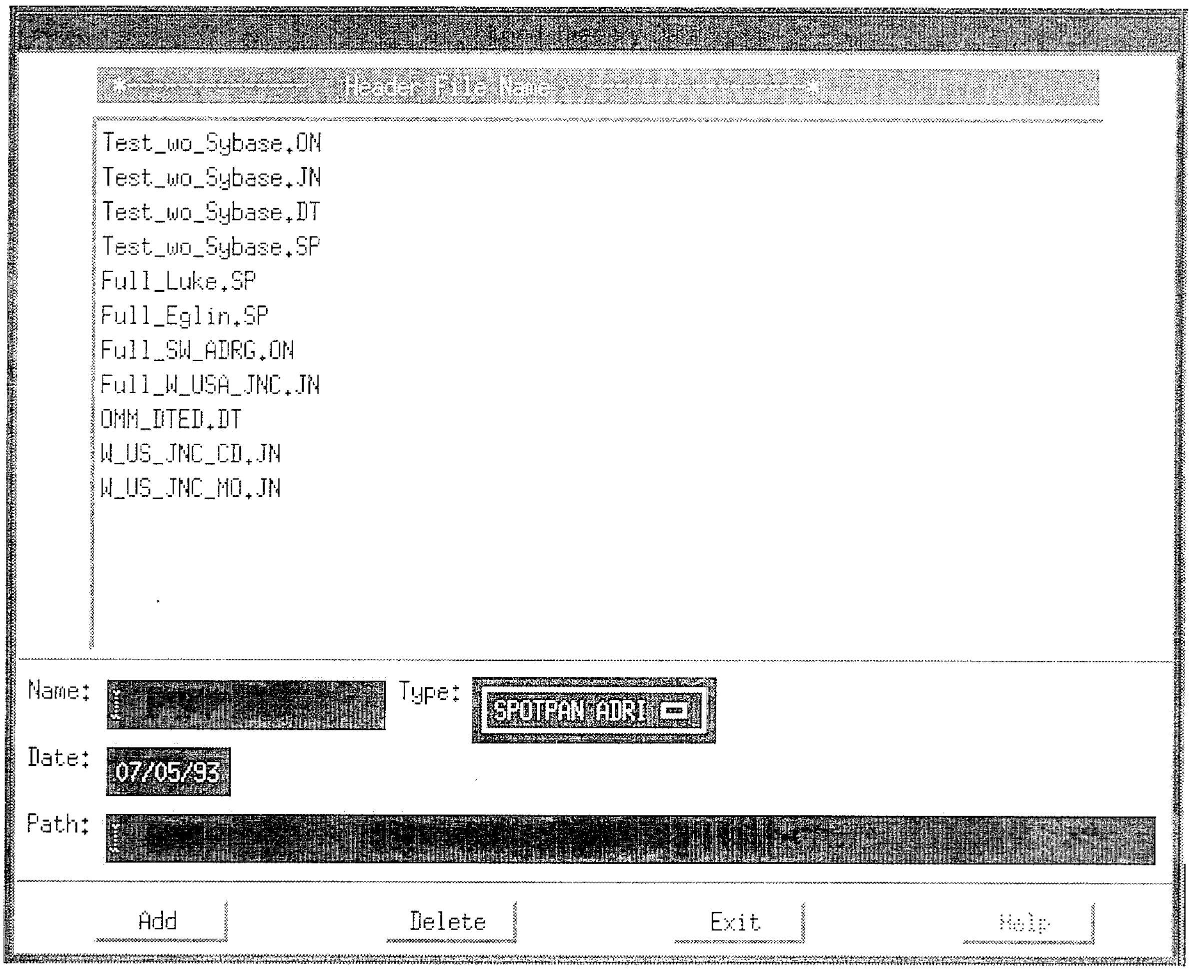
This option initiates the Imagery Header Load processing functions available to the operator. These functions allow the operator a means of adding/deleting/updating/ displaying imagery distributions information to/from the OMMAPS frame of reference.

When selected, the *Load Imagery Data* option generates the Imagery Load Dialog (see Exhibit B-10). This dialog is broken up into three (3) sections. The first section is a scrolled list of the imagery distribution file names recognized by the OMMAPS. The two-letter filename extension is generated by the system and indicates the type of imagery distribution stored. The following list indicates the values currently recognized:

- √ SP - Spotpan ARC Digital Raster Imagery (ADRI)
- √ ON ONC ARC Digital Raster Graphics (ADRG)
- √ JN - JNC ARC Digital Raster Graphics (ADRG)
- √ DT DMA Digital Terrain Elevation Data (DTED)

Following the Image Header list is the data interface section. Here, the imagery distribution information is entered and can subsequently be displayed. The last section consists of a series of four (4) control buttons that run along the bottom of the dialog. These buttons correspond to each of the functions available. However, the imagery load *Help* button , as with all *Help* buttons, is currently insensitive and can not be used.

Exhibit B-10 Imagery Load Dialog



B1.3.7.4.1 Selecting an Image Item

The operator can display the current information associated with an image header by double-clicking its corresponding list item. This will cause the application to populate the data interface area with the data currently found within the imagery data file.

B1.3.7.4.2 Adding an Image Item

When an imagery distribution is received, the operator must load the imagery distribution header data to a OMMAPS imagery file in order for it to be available to the OMMAPS system. This is done via the 'Add' process. To add an imagery distribution to the system, the operator enters the distribution's name and the directory where its associated data files can be found. The operator must also indicate the type of imagery data being loaded using the data type options menu. If this field is loaded incorrectly, the results may not be immediately apparent and could cause future processing problems that are difficult to resolve.

Once these values have been set, the operator then presses the *Add* button. The application will verify the data entered and then load the pertinent header data to the OMMAPS data files, storing the system date as the load date. If an error is encountered, the appropriate error dialog will be displayed. Once the load is successfully completed, the new imagery item will be added to the imagery item list.

The user may give to imagery distributions the same filename as long as they are both of different types. When the OMMAPS imagery object file is created, the two files will be differentiable by their respective filename extensions. If a new imagery distribution with the same filename and the same imagery type is to be added, the user will be prompted with to confirm the overwrite before it is performed. This allows the user a means of updating an existing imagery object.

B1.3.7.4.3 Deleting an Image Item

The Image Header Data Delete process is initiated by highlighting an image data list item and pressing the *Delete* button. The user will be prompted to confirm the deletion before it is performed.

B1.3.7.4.4 Exiting the Image Load Process

When Image Header processing is completed, the operator may popdown the dialog directly by pressing the *Exit* button.

B1.3.7.5 Recenter on Initial Point

During operation of the OMMAPS, at times it may be advantages to reset the imagery display to a known position. The *Recenter on Initial Point* option was defined with this in mind. The user may select this option at any time in any imagery display mode. When selected, the display will be recentered on the initial point for that imagery type within the current AOI. This point is calculated for each imagery type in each AOI and corresponds to the center point of the first imagery tile of that data type. This coordinate will only change if the imagery item configuration for that AOI imagery type is modified.

B1.3.7.6 Process Interest Points

While operating the OMMAPS, it is often useful to be able to quickly visit a specific point of interest without having to know its exact geographic location. This may be a position that is used as a point of reference or a particular position that the user will want to return to later for some reason. The OMMAPS offers a facility for doing this by allowing the user to save a set of geographic coordinates to point file and associate a label with them. When the *Interest Point* option is selected a secondary cascade menu is generated with three options. These options correspond to the Interest Point processing functions.

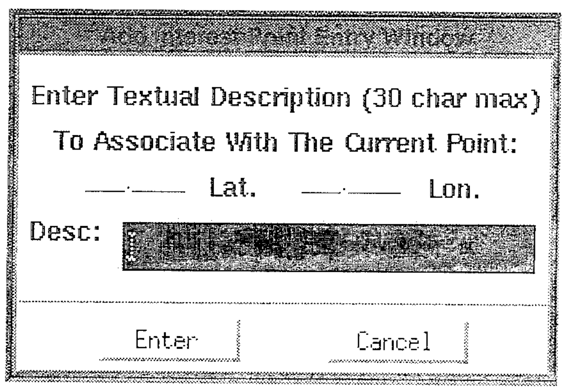
B1.3.7.6.1 Visit a Stored Point of Interest

The *Visit Point* option allows the operator to easily recenter the imagery on a stored point of interest. When pressed, the *Visit Point* button will generate a dialog containing a scrolled list of the current points of interest stored in the points file for this AOI. Each list item will include the interest point's name and geographic location. To visit a point the operator need only double-click the corresponding list item. When an item is selected, the list dialog will be popped down and the imagery will be recentered on the selected point of interest. The Textual Information Window data will then be updated to reflect the new system reference point. The operator may cancel the visit command by simply pressing the *Cancel* key on the list dialog. If there are no interest points associated with the current AOI, the appropriate error dialog will be generated.

B1.3.7.6.2 Add Interest Point

In order to save a geographic position to the points file, the operator must first center the Reference Point Indicator on the desired point. This can be done either by recentering the imagery on the point or using the *Set Current Point Here* point-positioning tool (see Left Button Options in the Pointer Device Controls section). Once the Reference Point Indicator has been positioned, the operator may then select the *Add Point* option which will generate the Interest Point Entry Dialog (see Exhibit B-11).

Exhibit B-11 Interest Point Entry Dialog



The Interest Point Entry dialog displays the geographic coordinates that will be associated with the new interest point and provides a field where the user may enter a description label to be associated with the point. This description may be up to 30 characters long. Once a description has been entered, the user simply presses the *Enter* button to add this point to the OMMAPS Interest Point File. This point will only be associated with and accessible from the current AOI. The user may cancel the process at any time by pressing the *Cancel* button.

B1.3.7.6.3 Delete Interest Point

The user may delete an interest point by selecting the *Delete Point* option. When this button is pressed, the user will be presented with a list of the current interest points associated with the current AOI. In order to delete one, the operator simply double-clicks the appropriate list item. The operator will then be prompted to confirm the deletion before it is performed and may cancel this process at any time by pressing the *Cancel* button.

B1.3.7.7 Exit OMMAPS

To end the current OMMAPS session, select the *Exit OMMAPS* option. A confirmation dialog is generated to avoid exiting the system inadvertently. The operator need only click the *OK* option to exit the OMMAPS system normally.

B1.3.8 MAGNIFICATION OPTIONS

There are two (2) selections found beneath the *Magnify* option in the menubar. These options are identical to those associated with the middle button of the pointer device. They are used to allow magnification processing to be controlled from the menubar.

B1.3.8.1 Magnify Full Resolution Imagery

Selecting the *Magnify* option causes the OMMAPS to magnify the image in the Full Resolution Image Window. The magnification process performs a simply pixel replication process on the center 'half' of the full resolution image. This results in a 2x magnification of the image. This process may be performed successively, it is, however, is very simple and uses no smoothing techniques. Each time it is performed, the image will appear more 'blocky'. This will become more and more apparent with successive magnifications until the image degrades to the point where it is no longer of any use.

The current magnification factor is displayed in the Textual Information Window relative to the base resolution. Once the image magnified, it is again overlaid with the mission paths and target information if this data is loaded and being displayed. The image will remain magnified until the operator either restores it to normal resolution, the imagery is recentered, or the reference imagery type is changed.

B1.3.8.2 Restoring to Normal Resolution

Selecting the *Restore* option will restore the image in the Full Resolution Image Window to normal resolution. The magnification factor in the Textual Information Window will be updated and the mission paths will be redisplayed, if appropriate.

B1.3.9 IMAGERY SWITCH OPTIONS

There are currently three (3) selections found beneath the *Switch* option in the menubar. These options allow the user to switch between the display imagery types available for each AOI. For each option, if the corresponding imagery type is not loaded for the current AOI, the selected imagery type is already being displayed, or the current Reference Point does not fall within that imagery's coverage, the switch will fail and the appropriate message will be displayed.

B1.3.9.1 Switch to Spotpan ADRI Imagery

Selecting the *to ADRI* option sets the current reference display imagery to Spotpan ADRI, if it is available.

B1.3.9.2 Switch to ONC ADRG Imagery

Selecting the *to ONC ADRG* option sets the current reference display imagery to ONC ADRG, if it is available.

B1.3.9.3 Switch to JNC ADRG Imagery

Selecting the *to JNC ADRG* option sets the current reference display imagery to JNC ADRG, if it is available.

APPENDIX C ADRI / ADRG COVERAGE

The following ADRI datasets, with the indicated approximate geographic coverage, were assembled into the test database used under the OMM ATD effort:

Area	Stock #	SW Lat	SW Lon	NE Lat	NE Lon
Korea - Northern	ADRI02SP8MM00019	39° N	124° E	43° N	131° E
Korea - Southern	ADRI02SP8MM00018	34° N	124° E	39° N	130° E
Turkey / Syria / Iraq	ADRI02SP8MM00028	36° N	38° E	39° N	44° E
Iraq / Saudi Arabia / Kuwait / Iran	ADRI02SP8MM00077	29° N	42° E	32° N	49° E
Yugoslavia	---	41° N	15° E	46° N	22° E

The following ADRG datasets, with the indicated approximate geographic coverage, wree assembled into the test database used under the OMM ATD effort:

Area	Stock #	SW Lat	SW Lon	NE Lat	NE Lon
Kuwait	ONCXXH06	24° N	41° E	32° N	53° E
Korea	ONCXXG10	32° N	116° E	40° N	130°E
Middle East	ONCXXG04	32° N	32° E	40° N	46° E
Saudi Arabia / Kuwait	JNCXX035	17° E' N	33° E	35° N	59° E
North Korea	JNCXX025	35° N	108° E	49° 30' N	135° E
North Korea	ONCXXF09	40° N	115° E	48° N	131° E

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